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ABSTRACT

This paper examines the implementation of 3D simulation through the development of the Avenor Virtual Trainer and how situated learning and fidelity of model representation become the basis for more effective Interactive Multimedia Training Situations. The discussion will focus of some principles concerned with situated training, simulation, interaction and immersion, which will help to set a background about the defining attributes of new virtual training systems. Through the Avenor project, the focus is on the instructional aspects of the technology and its importance in achieving a learning environment that challenges and supports effective training. (Contains 15 references.) (Author)

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The AVENOR VIRTUAL TRAINER PROJECT
a 3D Interactive Training Module on Energy Control Procedures : Development and First Validation Results

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Abstract

This paper seeks to examine the implementation of 3D simulation through the development of the Avenor Virtual Trainer and how situated learning and fidelity of model representation become the basis for more effective Interactive Multimedia Training Situations. The discussion will focus of some principles concerned with situated training, simulation, interaction and immersion which will help to set a background about the defining attributes of new virtual training systems. Through the Avenor project we will focus on the instructional aspects of the technology and its importance in achieving a learning environment which challenges and supports effective training.

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Introduction

Training has traditionally been considered in industry as a cost centered activity. It seems to be acquired that in short term, training consumes revenue. As main result, training is seen as the last response to some critical needs. While it is true that managers recognize that training is necessary to improve the human capital of an industry bringing employees to a level of proficiency that allows them to be more productive, the traditional concern keeping training at the absolute minimum remain prevalent.

In 1992, it has been estimated that American companies spent almost 30 billion per year on training (American Society for Training and Development, 1992). While this statistic could be impressive, it represents less then 1% of expenses on front-line workers. Moreover the traditional models of how educate and train does not reflect the evolution of the technology end emerging needs for different new kinds of skills.

Since then, an important reflection has emerged on new training models integrating new technologies and adopting more relevant design approaches. As a result of the introduction of advanced , computer-based training technologies compel companies, instructional designers, trainers and trainees to explore and adopt new learning models.

Much of the current research on learning and training in the context of formal training situations based their origins pointing out some depressing facts: employees, trainees, students in general are faced very often with a large amount of very complex skills, in sciences, mathematics, humanities. They can also successfully reproduce large amount of factual information on demand. They have enormous quantities of very precise knowledge. They can pass certifications, examinations successfully. But the main concern is that they are unable to show that they understand what they have learned. They are unable to build significant relationships among different kinds of information in order to apply and use them in an appropriate way depending on the context and specific needs. Interestingly, this problem is related on how and when a learner is acquiring new information to be transformed and integrated to become a new knowledge. Several studies stressed the importance of situated learning conditions while we are constructing new knowledge, letting the learner focus on real tasks in a problem solving situation.

Some studies already described this problem of "inert knowledge" which other researchers have further defined as knowledge that can usually be recalled when people are asked to do it, but it is not used spontaneously in a problem solving situation also if it relevant, because the way and conditions it has been learned (Cognition and Technology Group at Vanderbilt, 1990).

Interactive Multimedia as a technology in education seems to offer possibilities of allowing learners to participate in a more involving, meaningful and diversified learning situations, in which they can practice on real tasks and move from their status as a novice into the realm of an expert (Giardina and Brouillard, 1998).

In fact simulating a word in which the learner moves toward full participation, accessing the information according his specific needs, manipulating experiences and solving problems, should prove a powerful environment for understanding and also help with the transfer of concepts to new contexts.

Simulation training environments

As we already discussed, in contemporary theories of learning and instruction, learners are no longer considered as a person who merely reproduce knowledge or behavior that is presented to them by an instructional system, either instructor or technological environment, but more as active agent in his own learning process (Dede, C., 1995).This mind frame has led to new approaches to the design of instructional environments. One of these new approaches is scientific discovery learning or exploratory learning in which the learner is not given only direct instruction about the domain to be mastered, but he is invited to discover and apply the important concepts and relations in a domain by himself according with a given task (Jong., T. de, 1992).

The main assumption behind the exploratory learning approach is that knowledge discovered and refined by the learner will be based more precisely in the learner's attitude and knowledge configuration and have stronger links with learner's previous knowledge structures. The processes involved seem to be more intuitive and more qualitative in terms of relevant integration of new information in prior mental structures. In fact, the skills needed for the exploration itself are seen as important skills since they could help a person develop different strategies to deal with unfamiliar situations in more effective way.

These concerns have received a particular attention through the re-introduction of the Interactive training simulations as a powerful instructional device. As several studies already stressed, computerized simulations can fill in an important role as a training device for many reasons related as well to safety, economy, social reasons, as well to improve the possibility to access

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invisible processes or let the learner to manipulate real phenomenon (de Jong and *al.*, 1992; Shute, 1993, 1997; Grimes and Wiley, 1990).

More important, is the fact that through the simulation approach we can focus on exploratory or discovery learning strategies since it represents a model of a real situation to be discovered by the learner.

Effectively computer simulations are quite popular in instruction, but there is no conclusive evidence of their effectiveness and efficiency. Some researches showing positive effects (Shute and Glaser, 1990; Faryniarz and Lockwood, 1992), and others stressing the failure to find significant advantages of simulations (Jong and de Vries, 1993).

Some possible reasons for the ineffectiveness of computer simulation approach is that learners for example, while interacting with a simulation encounter difficulties which they cannot overcome on their own. The lack of guidance or the adequate execution of exploratory processes, the lack of accuracy defining or analyzing a problem (Joolingen and de Jong, 1991), the switching between personal hypotheses and actions to be taken in the simulated environment, as well as all the concerns related with the regulatory processes and the learner modeling (Giardina and *al.*, 1997; Shute, 1996; Giardina and Brisebois, 1996; Zhang.and Norman 1994).

Other major concerns seem to be focused on the exactitude and completeness of the representation of the simulated domain as well as in terms of graphical representation (2D or 3D), and in the over-complexity or over-simplicity of the conceptual representation of the situation.

Several possible solutions for these problems seem to emerge, among them new directions focus on the design of three dimensional simulated worlds that can increase their complexity interacting with the learner and providing learners also with support to access the information in multiple ways in addition to pure simulation (Giardina and *al.*, 1997).

The Avenor Virtual Trainer try to bring new ideas of instructional model through the implementation of both dimension, the most appropriate graphical representation of a given task and the possibility to build a conceptual representation through diversified access modes to the information. The major focus of this paper is to deal with some of these typical problems concerning the design of instructional strategies for learning with computers simulations. We should remember that when a learner is interacting in an simulated environment, we need a new way of monitoring the interaction, because the initiative is shared between the learner initiative and the system response. The next following paragraphs will describe more precisely some of these concepts, and they will be followed by a section describing the solutions proposed in the Avenor Virtual Trainer.

Situated Learning in simulated environments.

There is a great interest in the ideas conveyed by the situated learning approach as drawn on several studies about the social dimensions of the learning process (Vygotsky, 1978). Effectively, situated learning could be defined as the activity in which knowledge is constructed and deployed is not separable from learning and cognition, but an integral part of what is learned. The learner build a significant meaning through his continuous participation and involvement in his own learning process using and understanding tools allowing him to simulate authentic activities. This concept is central to many other studies that defined the learning process in terms of a continuum in between a novice state of skills an knowledge to an expert state. The learner through his immersion and interaction in a simulated situation, gradually moves from a peripheral involvement (novice) to a deeper involvement and understanding. Several observations stressed already the fact that one of the key issue in learners motivation is the perception of their actions, the assessment requirements and the guidance on what and how they are learning (Giardina and *al.*, 1992).

One of the major issue for the learner is to have the possibility to refine his understanding, and his potential to become a more expert practitioners in a given domain, through the interaction with a responding and adaptive situation. Many dimensions seem to be related to this concern, and one of the emergent one is the possibility to use the landscape concept to develop useful options in learning in this kind of simulated environment.

Immersion is one of the new concepts, which already some studies on virtual reality pointed out (Dede, 1996; Giardina and Brouillard, 1997) as a major component for a deeper understanding of specific procedural skills. Immersion and its effects on the user is partly function of the engaging and realistic aspects of the learning experience by computers. It could be very simple or very complex depending on the completeness of the representation of the situation, from complete range of sensory experiences to much more simple combination of sound and pictures. It can be argued that training meaningfulness result mostly in the effective use of relevant instructional strategies then on the merely physical representation of a situation.

Many authors discussed the concept of immersion, stressing that there are at least two main aspects that should be considered in relationship with learner involvement : physical perception and cognitive perception. Effectively we spent a lot of energies on the physical aspects of possible interactions between a learner and a system, it is common to several virtual reality projects and it is strongly determined by the devices through which the user manipulate the environment .

Another direction is the design of particular systems , as Avenor Virtual Trainer, that can be given a set of attributes and defined rules about the task or activity represented where the learner can directly manipulate elements of the simulated environment , move around exploring this particular microworld and receive specific hints and feedback on the correctness of his actions.

Another very important aspect of the immersion is the conceptual congruence between user's actions and their understanding of the knowledge embodied in the learning task. The importance of this concern is to make meaningful links between the decisions undertaken by the learner and the progress toward a possible solution. Early studies on simulation games clearly shown that the learner shouldn't achieve any significant progress only randomly selecting or making decisions completely on his own. We should be thinking in terms of giving him more simple to complex feedback, allowing him the possibility to select pre-established set of possible answers or some models of decisional path. More important within the interactive multimedia simulation the active involvement of the learner will lead to conceptual understanding directly about the situation in which he is working. This

is one of the major aspect that has been taken into account while designing Avenor Virtual Trainer (AVT). As we will see further , the AVT can allow different accesses to the same information, can provide several tools and diversified level feedback.

Fidelity of model representation

As we already stressed, in designing interactive simulation learning environments, one of the major concern is the domain model represented inside. Unlike in many traditional CBT learning environment , where the learner can only interact with some instructional design decisions carried by the system, within a simulation-based discovery system the model of the domain is represented, is executable and independent from the instructional strategy layer that could be added by the designer.

The interaction that results from this new kind of situations where learning complex skills relate to how the learner can move and manipulate objects efficiently in a three dimensional environments, has not been deeply explored. We argue that a novice that is attempting to process a large amount of knowledge trying to organize and integrate new information in his mental structure, he could be effectively involved if the domain model is realistic and allow him to operate as he was on the real situation. And this also if the simulation is implemented in a simple environment. By the nature of the interface and the three dimensionality of the interaction with this kind of context, learner cannot be passive, unlike in other learning situations that even implemented in a multimedia way present set of pre-established decisions in a very linear way. Effectively several study already expressed their doubts about a significant transfer of learning from a situation where the learner is not really stimulated to make decision on a realistic model to the real task.

Simulation models are designed to calculate the values of different variables from a given learner input. The potential of dynamic simulation is that a learner can manipulate these variables before or during on going interactions within the simulation seeing the results of his decisions. There is not a real problem, since the learner can focus on the single simulation and the system is only reactive to the learner actions and the procedural progression. A new challenge is when we want to add the instructional level as in a guided discovery environment (Dede, 1995, Dede and *al.*, 1996), the learning environment needs to be aware of the state of the simulation, the progression of the learner and the state of the instructional events that could be dependant in a specific context. As the design of the interaction is mainly focused on a mixed-initiative between the system and the learner each of these state may be changing at every moment, by a learner decision or by an occurrence of a specific event in the simulation. The instructional events should be aware of these changing states and they should be able to change the kind of interaction and guidance during the learning process, intervening directly on the simulated model or giving hints to the learner.

Meaningful learning practice in a simulation environment: Avenor VT

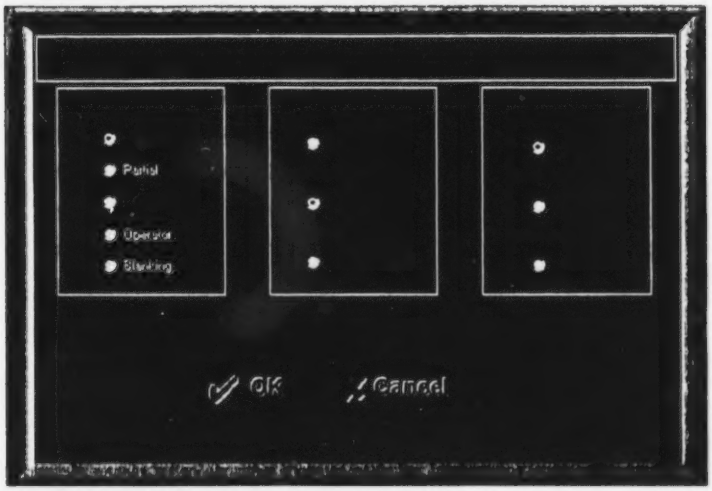
Several authors described crucial features related to way of thinking in a formal learning settings, focusing on the crucial aspects of situated learning and cognitive apprenticeship as powerful approaches to develop higher learning experiences. It has been argued that we should try to implement learning situations where we can observe, coach and practice to be effective. Where the novice-apprentice repeatedly observe a model mastering a given task or process, followed by an attempt of the learner to execute the task with a certain guidance (coaching) and ultimately reducing the participation of the system guidance (fading) as the novice can demonstrate the mastery of new skills. Furthermore, we should help the learners to articulate their knowledge, through reasoning or problem-solving process, enable the learners to reflect comparing their own problem solving process with those of an expert and finally but not less important, push the learners to explore more deeply in a problem solving mode on their own. We truly believe that we could rich a very meaningful learning experience through increased immersion, task realism, fidelity of representation and learner involvement Zhang and Norman, D.A., 1994).

Avenor Project Description

Interacting within the VT simulation

As we discussed previously, the learner at any moment can choose to interact in a different way and at different levels through the simulation. The main characteristic of Avenor VT, is that the learner can select to interact with different lockout procedures, from simple to more complex and he can learn, practice and refine these procedures playing different roles. He can switch from an *observer* learning strategy, watching *demonstrations* of TSL (Total System Lockout), PSL (Partial System Lockout), SEP (Safe Entry Procedure), and OL (Operator Lockout) Procedures, to a *practitioner* strategy through which he can *practice* performing TSL (Total System Lockout), PSL (Partial System Lockout), SEP (Safe Entry Procedure), and OL (Operator Lockout) Procedures.

For each Practice session, the learner can choose to play the role of the Operator (OP), the System Lockout Assistant (SLA), or the Person Performing Work (PPW). Naturally for each one of these different roles, the knowledge and skills to acquire and apply are different an complementary. The learner can analyze and define the task to be accomplished under different circumstances, in a different perspective and with several diversified constraints.



The feedback dimension during the interaction is very important, the learner depending the role and the procedure selected, receives contextual hints and feedback according to his actions and decisions. Object pop-up hints in the VR window are not provided during a Practice session to make things a little more challenging. However, the following feedback is provided:

1. Instructions are displayed in the *Status Bar* at the bottom of the screen. The learner can hide the instructions to simulate Practical Test conditions by clicking on the *Show Instruction* check box to remove the check mark.
2. A warning sound is played when the learner attempt to take an incorrect action.
   He cannot *fail* a Practice activity and his results are not recorded.

When the *Procedure* dialogue box will disappear the learner can start the practice activity.
When the practice starts, the *Play* button will change to a *Stop* button. At any time the learner can click on the *Stop* button to change the mode of interaction. Although, a practice activity cannot be paused, it must be completed from start to finish.
During a Practice session, the role the learner selected and the current role players will be displayed in the right-hand area of the screen. The selected role remains constant during the session, while the current role players will change as the situation changes.
For example, the picture shown below indicates that the learner has selected the Operator role and that the current role characters are the Operator and the System Lockout Assistant. In effect, this means that it is now time for learner (the Operator) to act because there is a match between the selected role player and one the current role players (figure 1).

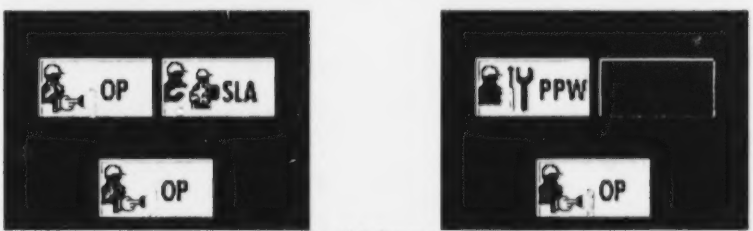


Figure 1: Possible learner roles in the VT environment

At times, the selected role player will not be one of the current role player(s). In these situations, the current role player(s) will act automatically and the learner will see a VR Movie of these actions.
For example, the picture shown below indicates that the learner has selected the Operator role and that there is only one current role player - the Person Performing Work. In effect, this means that it is not time for the learner (the Operator) to act because there is no match between the selected role player and one the current role players. Instead, a VT Movie will run which shows the Person Performing Work in action.
Other dimensions are also dispensable by VT when the learner immerse in the environment (fig.2). Some allows him to act as explorer, other as learner practicing some procedures or task.

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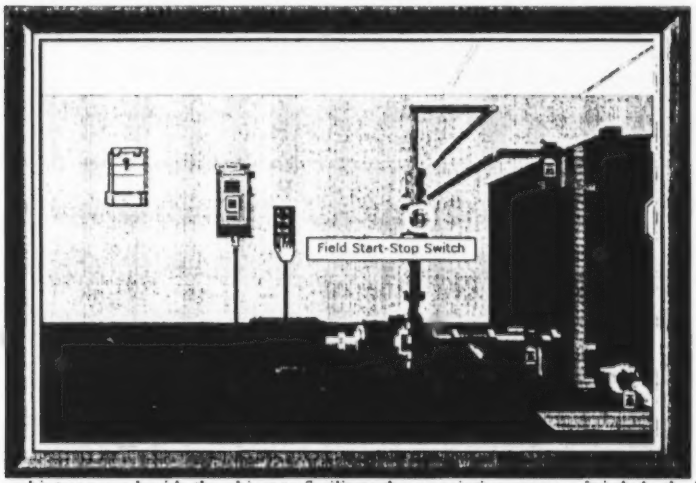
Figure 2: VT environment when the learner is practicing some specific task



Note here that the pop-up hint appears beside the object to facilitate the associative process. It is help the learner to become more selective activating discriminatory processes.
Table I resumes the principles dimensions available in the VT environment.

Table I: VT principles dimensions

VT Dimensions	*Learners possible actions*
Access mode	- *Logging-in*: create user-defined administrators, training supervisors and trainees. - *Explore mode*: the learner can browse around the 3D environment. He can select any of available - *Procedure mode*: the learner can watch demos of Lockout procedures. Ha can also practice them and test his skills with a Practical Test.
Exploration and practice	- *Looking around*: Its allows the learner to rotate his viewpoint to right or left. The learner has a complete control to explore the environments and he will receive only descriptive feedback. Its allows him to built a declarative understanding of the situation. - *Finding object*: by moving the mouse, the mouse pointer changes to a hand shape and identify the objects as one that the learner can get a definition and a quiz question for. It allows learner to be more selective activating discriminatory processes. - *Selecting object*: selecting an object, an image appears in the Current Object panel giving the learner Object Name Panel and a Definition panel appears in the lower-left area of the screen. - *Manipulating objects*: the mouse pointer changes to a fist when it is over object. This means that the learner can manipulate the object by clicking on. By zoom-out moving the learner has the possibility to see better significant details of a particular elements and refine his action or decision. - *Getting the tools*: during the interaction, when the learner is in Procedure mode, he can practice and test his skills in performing an Energy Control Procedure. A feedback will be given in order to guide him to select the right set of tools. - *Applying the tools*: the learner is asked to manipulate a specific object adjusting to the right position. The interaction lead the learner to activate several learning process, observing, moving around the object, selecting the right procedures to be applied and manipulating more in detail the tool elements.

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Formative evaluation	- *Taking the pre-test*: if the learner log-in as a trainee, he should first take the Pre-Test in order to determine his current level of knowledge about Energy Control Procedures. - *Taking a formative* quiz: in explore mode, the learner can identify his knowledge about an object or a specific task. The learner can choose a specific context in which he want or hi is acting. The feedback provided help with several hints and suggestions for further actions or decisions. - *Taking a practical test*: At the end of a series of manipulations for a given task, the learner can take Practical Test. If he takes an incorrect action, an information is provided about the action he attempted to take and the correct action that was required.

The user has other generic tools that can use at any time during his/her interaction within the system. As:
- Keeping a Diary
- Training Supervisors.
- Checking a Trainee's progress
- Training Management

Validation Methodology and some Findings

We had a three phases validation process: functional validation, pre-validation and validation.

During the functional validation, we have asked 5 Instructional Designer to interact with Avenor VT and take notes on a pre-designed matrix (Giardina and *al.*, 1997.. The main objective of this step was to verify the functioning of the Virtual Trainer situation and all its functions.

Several points arise from this preliminary validation and they could be summarized as follow :

- the importance of the availability of mapping tool, helping the user to not getting lost within the content and the simulated environment.
- the necessity of different color codes for different kind of possible manipulations during the simulated activities .
- the importance to focuses more on the activation of selective perception (visual and audio), by the integration of specific visual and audio hints.
- the importance to diversify several feedback levels focusing on the general problem solving process and on the very contextual action that is occurring.
- the importance to maintain a consistent language level within the several possible categories of textual and audio messages (ex. definitions, guidelines, helps).
- the necessity to integrate spatial hints to decrease the lack of orientation.

After this functional validation several changes have been incorporated into the Avenor Vt.

During the second phase, the pre-validation, we have asked 5 practitioners (target population) to interact with the system for at least one hour. During the interaction we have observed the interaction process with an observation grid designed to collect some attitudinal aspects (ex. curious, interested, nervous, serious, amused, concentrated) as well as some external verbal behavior (ex. exclamation, comments, questions on technical or navigational aspects, on learning activity). A trace has been also recorded by the system, keeping trace of some activities results, wrong or good answer, etc.

At the end of the interaction session (60 to 90 minutes) we collect some students' impressions with a structured interview . The design of each question was directed by our predictions about how simulated environments and realistic tasks impact learning process. We coded the responses using the following framework :

- General topics
- Navigational and Interaction tools
- Potential learning actions by the learner
- Coaching strategies by the systems
- Similarities with real tasks
- Multimedia content representations
- Motivational aspects.

As a very global synthesis of the results:

- the learners find the environment very challenging and stimulating.
- the learners find that their engagement within learning activities was as well and reach as in the real environment, sometimes also better.
- they pointed out the multiplicity of content representation as one of the major factor, as well as the possibility of several manipulations during the activity.
- the learners consistently rated this experience to be most like real work, or real on the job trainirg situation.
- they characterized positively the possibility to manipulate directly making errors, seeing immediately the consequences and having the possibility to refine their decision.
- the learners seemed to prefer an audio comment while they were manipulating an element.
- they justified the audio preference by an increased concentration on the task.
- the challenge and the complexity of the activities seemed to maintain the learners interest.
- the fact that all the students tried very hard to accomplish all the tasks solving the different problems presented to them, suggest that the learners were truly engaged in the activity.

- the learners stressed the importance of the very situated feedback they received, as a key factor to maintain and increase their confidence.
- our data suggested also that diversifying and increasing the realism and the complexity of the activity in a real engaging and meaningful process, can increase the student learning expectations.

After this pre-validation step, we reformulated some questions of the structured interview that were to much answer-inductive and we refined some question items based on some emerging unexpected points. (ex. redundancy between textual and audio messages, possibility to personalize several parameters during the learner interaction, ex. time., risk, etc.).

During the validation phase we asked 18 operators (target population) to interact with Avenor VT and we used the same revised collecting tools (observing grid, trace and structured interview) as in the pre-validating phase.

Analyzing, condensing and presenting the data, we observed several results :

- the users that have already a better understanding of the task they perform better during the simulation
- the users that have more refined mental model of the simulated environment they interact in a deeper way and they try more complex activities.
- the users that have no mental model of the simulated environment or task they get lost much easier and more frequently.
- the users' ability to refine or build such mental model depend on the time spent to interact with the system.
- the possibility to access multiple representation and manipulation of an activity seems to reduce considerably the time to build a more precise mental model of the task.
- the possibility to make errors during the activity, see the realistic consequences and have the possibility to readjust our decision seems to have a direct impact on the learning time.
- the possibility to choose different role to play during the interaction with the system, seems to bring a deeper understanding of the problems related to the real task.
- the majority of the users mentioned the importance of the feedback dimension and stressed the necessity to improve it, situating and diversifying more the messages.
- most users have employed the demo state of the system before the practice.
- the majority of the users seemed to use the formative quiz as a learning tool during the interaction, to self-assess the lack of understanding during interaction with the system.
- the interaction through a reactive simulated training environment seems to build a deeper confidence for the learner to solve complex situations.

Conclusion

Within the Avenor Virtual Trainer project, we tried to integrate the new potential of both the technology and learning strategies to improve the possible understanding during the learning process.

Of course we related in this article only a synthesis of some findings that we think could give some interesting directions of reflections .

Effectively the project has been designed to improve the access to an information simulated environment through several different tools and dimensions provided to the learner by:

- Elaborating accessible and useable tools to allow the learner to meaningfully interact within a multimedia representation of a situation.
- Providing an adaptive textual and audio feedback and coherent navigational and information metaphor which requires minimal explanation for the learner to understand and manipulate it.
- Supplying several problems and tasks to solve based on the information embedded in the simulation.
- Providing a formative evaluation dimension along the all learning process as well as a pre and post test evaluation to have some indications in terms of learning gain.

It seems to us that this study on Interactive Simulated Training Environments let emerge the importance of continuing the research and development on the pedagogical integration of new technology within the learning process. Already some concerns related to this experience seem to suggest that learning strategies such as exploration, simulation , problem solving, personalized feedback among others, if they are systematically designed and implemented in a realistic mediated situation can have an important impact on cognitive and affective dimensions of the learning process.

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